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THE RELATION OF HIGHWAY SLASH TO INFESTATIONS BY THE WESTERN PINE BEETLE IN STANDING TIMBER

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INTRODUCTION

Foresters have generally recognized three types of slash: Logging slash, or waste left on the ground after logging operations; line slash, which results from clearing roads, power lines, and telephone lines, and occurs in long narrow strips, instead of the compact bodies which characterize other types; and wind-blown slash, consisting of entire trees which have been blown down and of tops and limbs broken down by wind and snow.

For many years the problem of slash disposal has been before foresters and lumbermen. The value of slash disposal as a forest practice and the merits of various methods of its accomplishment are subjects which have been widely discussed. The problem was complicated by insect infestations, which are generally known to occur in slash, because until recently little had been done to make a scientific analysis of the relation between such infestations and infestations in surrounding standing timber.

Foresters have long known that slash is a favorite breeding ground for certain forest insects, and forest entomologists have known that slash and insects are closely related, slash of whatever kind and wherever occuring being usually infested by one or more species of two groups of forest insects commonly known as bark beetles and borers. As these infestations are by many believed to constitute a menace to adjacent standing trees they are of special interest to foresters and owners of timber.

Reliable quantitative data on the interrelation of slash and insects have been very meager. To determine more definitely whether the

infestations here mentioned threaten the value of adjacent standing timber, the Bureau of Entomology undertook investigations of their characteristics. The results of a study of line slash in western yellow pine (*Pinus ponderosa*) in southern Oregon are reported in this bulletin. The western pine beetle, *Dendroctonus brevicomis* Lec., is the principal insect enemy of the mature western yellow pine in this region, and the present study resolved itself into an analysis of the habits of this species in the slash in question, and of the influence of the slash infestation upon the infestation in the surrounding standing timber.

The details of the study consisted of investigations relating to the character of the attack made by the insect on the slash, the development of the brood in the slash material, and the degree of infestation occurring in the mature standing timber on the adjacent territory during the attack on the slash and after emergence from it of the developed broods. Points of special importance to reliable conclusions were the selection of a location typical of large areas of timber; the technic of determining the attack, development, and emergence of the insect infesting the slash; the comparison of these events with their equivalents in normal infestations of standing timber; the determination of the amount of the surrounding normal infestation; and the amount of infestation developed in the adjacent timber following emergence from the slash.

The study here reported covered the period from May 1, 1920, to October 1, 1924. The area wherein the slash was located had, however, been surveyed annually since 1915, and the data on previous insect losses which were made available by these surveys add much to the reliability of the conclusions here drawn.

THE AREA

The area in which the study was conducted lies in the Cascade Mountains in southern Oregon. It is a belt of timber about 7 miles wide, extending 20 miles from east to west, and containing about 76,000 acres, with elevations ranging from 3,000 to 5,000 feet. Deep canyons worn by the streams, and intervening steep ridges, make the topography of the western part of the area much more rugged than that of the central and eastern parts, which partake more of the nature of the high plateaus typical of the interior basins.

The timber stand is a mixture of western yellow pine (*Pinus ponderosa*), sugar pine (*P. lambertiana*), Douglas fir (*Pseudotsuga taxifolia*), and white fir (*Abies concolor*), typical of the mountainous interior of southern Oregon and northern California. Above this mixture, on the higher elevations, are pure stands of true firs (species of Abies), and below is found the belt of pure yellow pine characteristic of the forests of the interior plateau region. There is a higher percentage of pine in the central and eastern parts of the area than occurs in the western portion. The total yellow pine stand is 808,000,000 board feet, averaging a little more than 10,500 feet per acre

THE SLASH

The history of the slash dates from November, 1919, when the highway commission of Oregon commenced construction of a State highway through the area just described. The first trees were felled

at the west end of the right of way at the summit of Greenspring Mountain. The felling of the timber between this point and Jenny Creek, 10 miles to the eastward, was done between November 11, 1919, and May 20, 1920. The trees on a second portion of the highway, extending a distance of 14 miles from Jenny Creek to Hayden Creek, were felled between October 20, 1921, and June 20, 1922. The slash was laid down in every calendar month except July, August, and September, so that it was possible to obtain data on slash made in each of the other nine months. Another valuable feature of the slash in this area was its division into two portions, one dating about two years earlier than the other. This permitted a study of similar events pertaining to attack of the insects, and to previous and subsequent infestations in the same general area, but separated by an interval of two years, in which the cycle of periodical infestations reached a peak and declined.

The slash itself consisted of the entire trunks and tops of trees felled, limbed, and dragged to either side of a strip 60 feet wide and 24 miles long. Where the timber was dense the logs were placed in lots of from 3 to 10, but the slash was mainly left as individual logs placed separately along the edges of the clearing.

THE LINE OF INVESTIGATION

This study was undertaken chiefly to determine whether or not beetles breeding in slash would increase the subsequent infestation in the surrounding mature timber. To this end a comparison was made of the proportion of felled trees in the slash which were attacked by bark beetles, and the proportion from which broods emerged, as an indication of the degree of attractiveness of slash for beetles, and the adaptability of the slash as a breeding place for them. The most significant data bearing on this question were obtained from a quantitative study of the loss, both in number of trees and in board feet of lumber, resulting from the attacks of bark beetles, in standing timber adjacent to the slash. Another inquiry in this connection was directed to the influence of the slash on the concentration of attacks of the bark beetle on the standing timber near it.

INFESTATION OF THE SLASH

To investigate the relationship of the slash to the attack and breeding of bark beetles, 1 square foot of bark was taken from the middle of the butt log of each felled tree after the emergence of the broods, and the entrance holes and the exit holes in it were separately counted. These data were then compared with corresponding data from standing trees which had been attacked by bark beetles.

The western pine beetle, *Dendroctonus brevicomis*, which in this region attacks only western yellow pine, was the only bark beetle occurring in numbers sufficient to warrant study. Other bark beetles found infesting the slash were *D. monticolae* Hopk., *Ips emarginatus* Lec., and *I. confusus* Lec. The entrance and exit holes of *D. brevicomis* only were counted in this investigation.

The trees in the first section of the highway, between Greenspring Mountain and Jenny Creek were felled in November, 1919, and March, April, and May, 1920, and were attacked by the bark beetles

in the latter part of May and in June, 1920; those in the other section, between Jenny Creek and Hayden Creek, were felled in October, November, and December, 1921, and in January, February, May, and June, 1922, and were attacked in the two months last named. The fact that 97.5 per cent of all the trees felled were attacked by bark beetles indicates the great attraction which slash has for these insects. The broods which developed from these attacks emerged during July and August, and the trees were examined, and the bark counts made, in September.

A study of the infestations by bark beetles in standing mature yellow pine trees in this region at the same time showed that on an average, under normal conditions, there are 23 attacks and 54 emergences per square foot, the emergences numbering 235 per cent, and the resulting numerical increase 135 per cent, of the attacking insects. In the felled trees of the slash there were found to be an average of 11 attacks and of 18 emergences per square foot, the emergences numbering 164 per cent, and the increase 64 per cent, of the attacks. These data afford evidence of the high relative mortality which attends the breeding of bark beetles in slash, as contrasted with normal broods developing in standing trees. As the condition of slashed trees is approximately the same wherever they are found, the data obtained on slash in other areas will not be very different. Indeed, the results of studies of other slash indicate that these figures may be taken as a general average for all types of slash. Some differences have been found in the statistics of infestations in mature standing trees, because of the many factors influencing the cycles of infestation of *Dendroctonus brevicomis*. The average figure which has been given for mature timber was determined on this area for purposes of comparison and is not intended to represent a constant value.

It is to be seen that the attacks per square foot in the felled timber of the slash numbered slightly less than half of those in the standing trees. It may be added that because abnormal conditions in slash are directly responsible for a high mortality in the brood which it harbors, it follows that the effective progeny are materially decreased in numbers.

Besides the study just described, based on the examination of a square foot of bark from each felled tree, a count was made of those trees, and the corresponding volume in board feet of the lumber was computed. It was found that in the entire slash 1,075 trees had been felled, containing in all 1,557,690 board feet; of these, 1,048 trees, or 97.5 per cent of the total, containing 1,516,730 board feet, or 97.4 per cent of the total content, had been attacked by bark beetles. Of the 1,048 trees attacked, 901, or 86 per cent, containing 1,401,920 board feet, or 92.4 per cent of the total content, were found to have been the breeding places of broods which had emerged. The significance of this high percentage is not, however, so great as might be at first supposed, for most of these broods suffered an abnormally high mortality in the larval and pupal stages, with the result that the new adults which emerged were in the case of many trees fewer in number than the parent adults which entered the slash. This abnormal mortality was caused chiefly by changes in the moisture content of those portions of the tree which constitute the food supply of the developing beetle.

INFESTATION IN ADJACENT STANDING TIMBER

One object of this study, dealing with the infestation of slash by bark beetles, has been discussed. The major object was to determine whether or not bark beetles breeding in slash would increase the subsequent infestation in the mature standing timber near by. Another object, closely related, was to ascertain whether the freshly made slash attracted bark beetles, with resulting concentration in the adjacent standing timber.

TABLE 1.—*Loss by years in trees and in equivalent board feet from attack of bark beetles on standing timber adjacent to highway slash*[1]

INTENSIVE ZONE

Year	Loss in section 1			Loss in section 2		
	Trees	Board feet	Board feet per acre	Trees	Board feet	Board feet per acre
1918	330	281,000	27.4	98	120,000	7.2
1919	437	372,000	36.3	120	155,000	9.3
1920	479	519,000	50.7	162	178,000	10.7
1921	227	247,000	24.1	93	165,000	9.9
1922	367	390,000	38.1	140	219,000	13.2
1923	262	289,000	28.2	228	301,000	18.1

REMOTE ZONE

1918	363	308,000	10.2	700	650,000	33.9
1919	344	330,000	11.0	860	810,000	42.2
1920	702	632,000	21.0	920	920,000	47.9
1921	889	756,000	25.1	770	693,000	36.1
1922	598	600,000	19.9	557	501,000	26.1
1923	460	414,000	13.8	610	591,000	30.8

BOTH ZONES

1918	693	589,000	14.6	798	770,000	21.5
1919	781	702,000	17.4	980	965,000	26.9
1920	1,181	1,151,000	28.5	1,082	1,098,000	30.6
1921	1,116	1,003,000	24.9	863	858,000	23.9
1922	965	990,000	24.6	697	720,000	20.1
1923	722	703,000	17.4	838	892,000	24.9

[1] The slash in the first section was felled after the observations made in 1919 and before those of 1920; that in the second section between the observations of 1921 and those of 1922. The dotted lines indicate in the several cases this relationship.

TABLE 2.—*Total loss by years in trees and in equivalent board feet from attack of bark beetles on standing timber adjacent to highway slash*

Year	Trees	Board feet	Board feet per acre	Year	Trees	Board feet	Board feet per acre
1918	1,491	1,359,000	17.8	1921	1,979	1,861,000	24.4
1919	1,761	1,667,000	21.9	1922	1,662	1,710,000	22.5
1920	2,263	2,249,000	29.5	1923	1,560	1,595,000	20.9

In pursuit of the major object an annual survey of the area was made in July and August from 1918 to 1923, inclusive, to determine in each year the loss, in number of trees and their equivalent in board

feet, occasioned by the attack of bark beetles from the broods emerging in that year.[1] The timber adjoining the slash felled in 1919 and 1920 is here called the first section, and that adjoining the slash created later the second section. A strip of timber about 1 mile wide on each side of the slash, approximately paralleling it for its entire length, is called the intensive zone;[2] the timber concerned lying beyond it is called the remote zone. Because of the topography the outer boundaries of the remote zone are irregular and at varying distances from the slash. In making these surveys the statistics for each zone, in each section, were kept separately. For the answer to the question, Did the new slash cause a concentration of bark beetles in the adjacent timber? a cruise of the intensive zone was made in July and August in each of the six years and a comparison made, one year with another, of the loss in board feet per acre. The results of these surveys and cruises, by sections and zones, are presented in Table 1, and a summary for each of the six years, for the entire area, including both zones, in Table 2. A dotted line is inserted in each portion of Table 1 to indicate the time when the slash was created in the section concerned, relatively to the times of the six annual surveys in both the intensive and remote zones, and the six annual cruises in the intensive zones. In the first section these observations were made for two years before and four years after the felling of the slash; in the second section these numbers are reversed, being four and two, respectively. The acreage of each section in each zone was as follows:

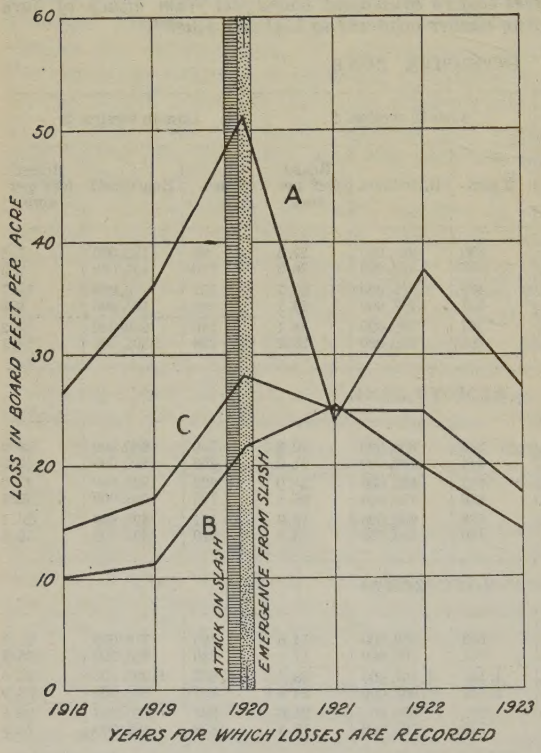

FIG. 1.—Annual losses in board feet per acre of standing timber killed by the western pine beetle in the zones of section 1, adjoining slash felled in 1919 and 1920. A, losses in intensive zone; B, losses in remote zone; C, average losses in board feet per acre for both zones. The observations for determining these losses were made in July and August of the respective years, and the locations of the vertical lines represent the beginning of August for those years. The shaded space on either side of the line for 1920 represents not only the time of the survey for that year but also the time of emergence of beetles from the adjacent slash; the shaded area to the left of this, the time of attack on the slash

[1] The standing mature trees were attacked in May, June, July, August, and September. The attack of this beetle is continuous throughout the period from May to September, and the emergence from the brood trees is also continuous during this period. The reason why the slashed trees were not attacked at any time except during May and June was because none of them were felled in the summer period of attack—i. e., July, August, and September. Those felled from October to May were not attacked until the following May because there is no flight or attack in this or in the winter period. For the same reasons there was only one period of emergence from the felled trees.

[2] Owing to numerous sharp curves of the highway it is a few miles longer in each section than the corresponding intensive zone.

	Section 1	Section 2
	Acres	*Acres*
Intensive zone	10,240	16,640
Remote zone	30,080	19,200
Both zones	40,320	35,840

As these tables indicate the progress of the infestation in the standing trees for the six years indicated, the effects, if any, of the breeding of bark beetles in the newly made slash should be reflected in the behavior of this infestation as shown by the number of board feet killed per year. It may be seen from the figures that in the intensive zone, in each section, the loss increased in the year the slash was attacked and infested, indicating that a concentration of the beetles was brought about by the attraction of the fresh slash material, thus apparently answering the second of the two questions it was hoped that this study would decide. It is, however, further shown by the figures that this concentration was not permanent in either section, the surplus of the infestation being soon dissipated in the surrounding timber.

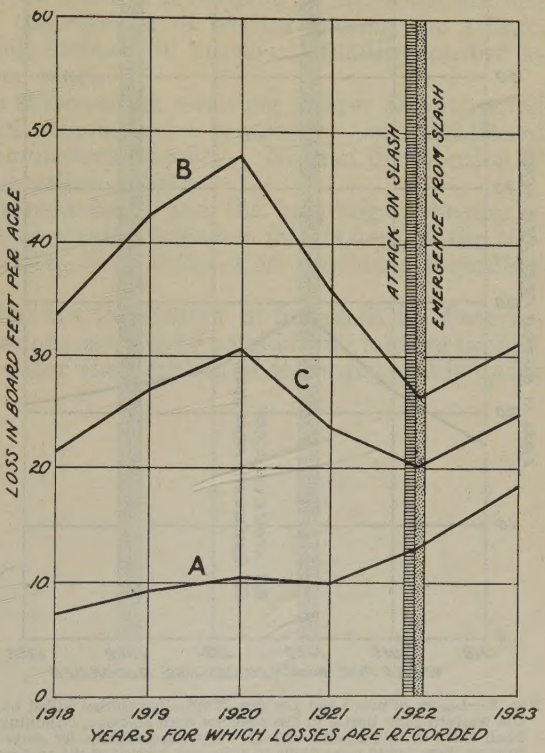

FIG. 2.—Annual loss in board feet per acre of standing timber killed by the western pine beetle in the zones of section 2, adjoining slash felled in 1921 and 1922. A, losses in intensive zone; B, losses in remote zone; C, average losses in board feet per acre for both zones. The observations for determining these losses were made in July and August of the respective years, and the locations of the vertical lines represent the beginning of August for those years. The shaded space on either side of the line for 1922 represents not only the time of the survey for that year but also the time of emergence of beetles from the adjacent slash; the shaded area to the left of this, the time of attack on the slash

It may be further seen from Table 1 that in both sections of the intensive zone, and in the first section of the remote zone, the loss in the standing timber, in numbers of trees, equivalent board feet, and board feet per acre, was somewhat larger in the year following the attack and emergence of bark beetles in the slash than in the preceding year; whereas in the second section of the remote zone these relations are reversed. According to the combined figures for both zones, the loss in similar terms was in the first section greater, and in the second section less, after the infestation and emergence, than it was before.

It seems plain that in the remote zone the infestation of the standing mature trees was not in any way influenced by the infestation of the slash. In the intensive zone, in the first section the infestation of the standing mature trees was nearly 40 per cent, and in the second section 33 per cent, greater in the year after the infestation than in the year preceding it, if the relative infestation be measured by the total loss in board feet, and the loss in board feet per acre. The temporary concentration of attack in the standing timber near the slash, already mentioned, seems to be the one net result of the infestation of the slash. The conclusion, derived from data presented in Table 1, seems plainly to be that the slash had no effect whatsoever on the progress or cycle of the infestation in the surrounding timber during the six years in which observations were made.

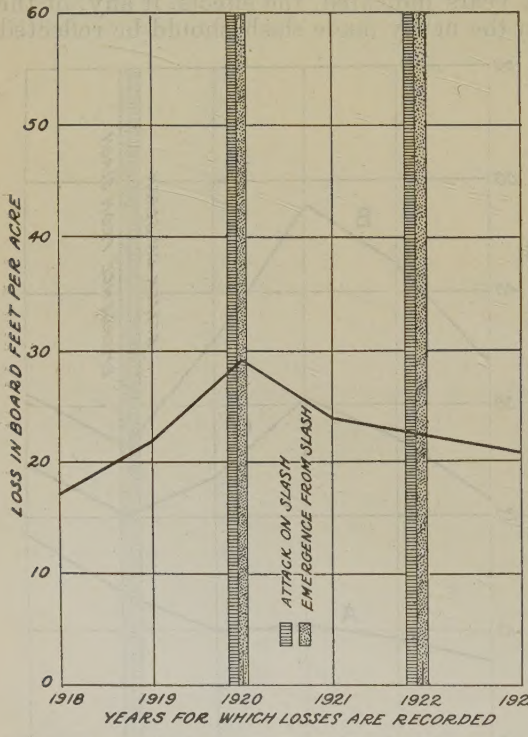

FIG. 3.—Losses in board feet per acre of standing timber killed by the western pine beetle in the zones of both sections, adjoining slash felled in 1919–20 and 1921–22. The observations for determining these losses were made in July and August of the respective years, and the locations of the vertical lines represent the beginning of August for those years. The shaded spaces on either side of the lines for 1920 and 1922 represent the times of survey in those years and also the times of emergence of beetles from the adjacent slash; the shaded areas to the left of them the times of attack on the slash in the first and second sections, respectively. The curve shows the cycle of infestation in the zones of standing timber for the six years of the study

The statistics relating to loss in board feet killed per acre are represented in graphical form in Figures 1, 2, and 3. Figure 1 shows by separate curves the loss for each zone, and the total for both, in the first section; Figure 2 gives similar data for the second section, and Figure 3 shows the cycle of the infestation through the periods of attack and emergence in the slash and in the standing timber throughout the period of the study. The infestation, beginning at a relatively low point in 1918, reaches its peak in 1920 and declines to a low point in 1923, passing through this normal cycle regardless of the influence of the slash. The major question dealt with in this study—whether the infestations of standing timber are increased through the breeding of the insects in neighboring slash—is thus answered in the negative, so far as a single carefully conducted investigation can answer it.

SUMMARY

Line slash of the character here considered is very attractive to the bark beetle *Dendroctonus brevicomis*, practically all such slash being attacked by this insect.

The attack of this bark beetle on the slash is not so heavy as its attack on mature standing timber. In the particular case studied approximately one-half as many beetles attacked a unit area of bark on the felled trees as attacked an equal area on standing timber.

The broods developing in slash are characterized by abnormal mortality. The increase of beetles developing in the slash studied was only 64 per cent of the number of beetles making the attack, whereas the corresponding increase in adjacent standing timber at the same time was 135 per cent.

Bark beetles from the surrounding standing timber are attracted to the slash at the time of attack, and a temporary concentration of infestation occurs in its immediate vicinity. Normal distribution of the infestation is resumed within a year.

The concentration just mentioned and the breeding of beetles in line slash do not increase or greatly influence infestations in the surrounding forests. The cycle of an infestation continues regardless of the slash.

This study indicates that the infestation of line slash by *Dendroctonus brevicomis* is not a serious menace to neighboring mature timber, and may be disregarded when the problem of slash disposal is under consideration.

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